Climate Change and Soil Processes

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Introduction

- This presentation is based on Brevik (2012); references for the statements made in it can be found in that publication
- Average global temperature will probably rise between 1.1°C and 6.4°C by 2090–2099 as compared with 1980–1999 temperatures
- The most likely rise is between 1.8°C and 4.0°C
- Precipitation patterns will also change
- The soil-climate system is intricately linked, therefore, changes in the climate system will influence soils and vice versa

Soils and Gas Fluxes

- Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) make up the majority of anthropogenic greenhouse gas emissions
- These gases are a part of the global C and N cycles; soils are also part of the C and N cycles, this links soils and the atmosphere

Soils and CO_2

- The largest active terrestrial carbon pool is in soil
- Soils may be either a source or sink of C, depending on the balance between additions to and emissions from the soil (Figure 1)
- Human management, including tillage, crop rotations, cover crop use, and drainage can influence the soil C balance
- Other environments that show potential for significant C sequestration in soils include coastal (saltwater) wetlands and abandoned mine/quarry sites
- Melting Arctic soils are of particular concern in terms of the release of carbon to the atmosphere

Soils and CH_4

- Agriculture accounts for about 47% of annual global anthropogenic emissions of CH_4
- The main anthropogenic source of soil-derived methane is rice (*Oryza sativa* L.) production, while natural soil-derived methane comes primarily from wetlands (Figure 2)
- Increasing soil temperatures lead to increased CH_4 production in rice paddy soils and wetlands
- The melting of permafrost soils is also becoming a major source of atmospheric CH_4
- Soil management that influences CH_4 fluxes from soil includes
  - choice of N fertilizers (presence of NH_4^+ inhibits ability of the soil to sequester CH_4)
  - reducing period of soil saturation during rice production decreases CH_4 production (but increases N_2O production)
  - organic amendments added to saturated soils increases CH_4 production
  - P fertilizers decrease CH_4 production

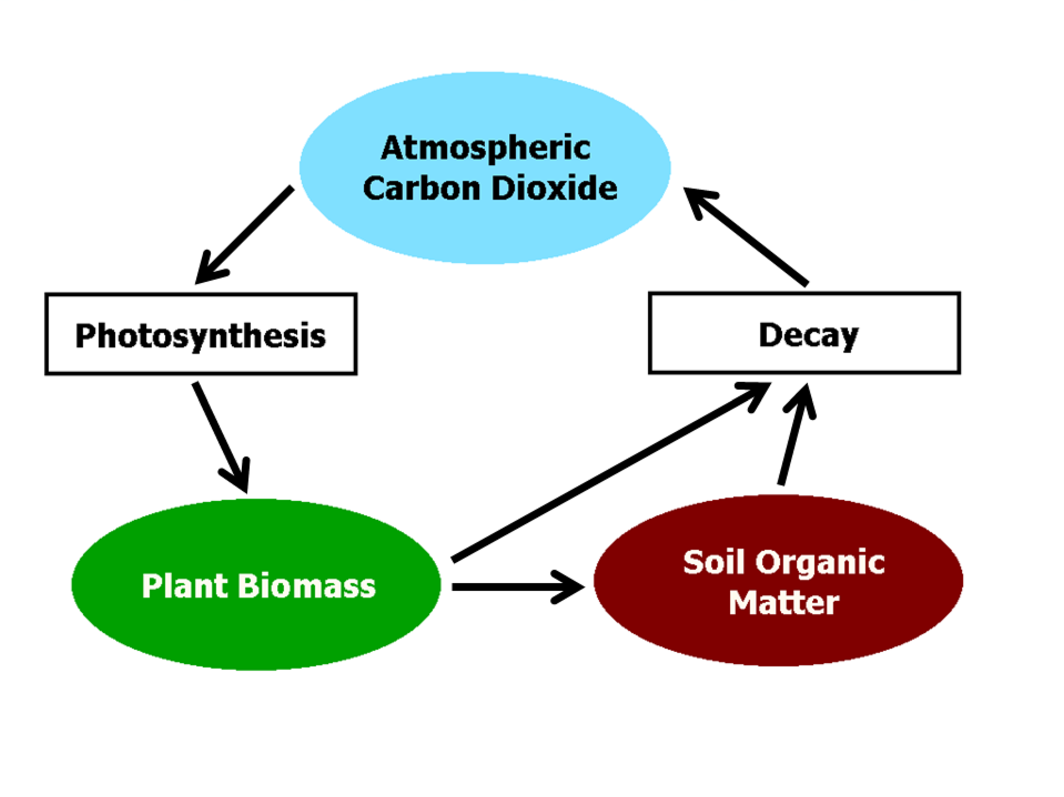

Figure 1. A simplified depiction of the links between atmospheric and soil carbon.

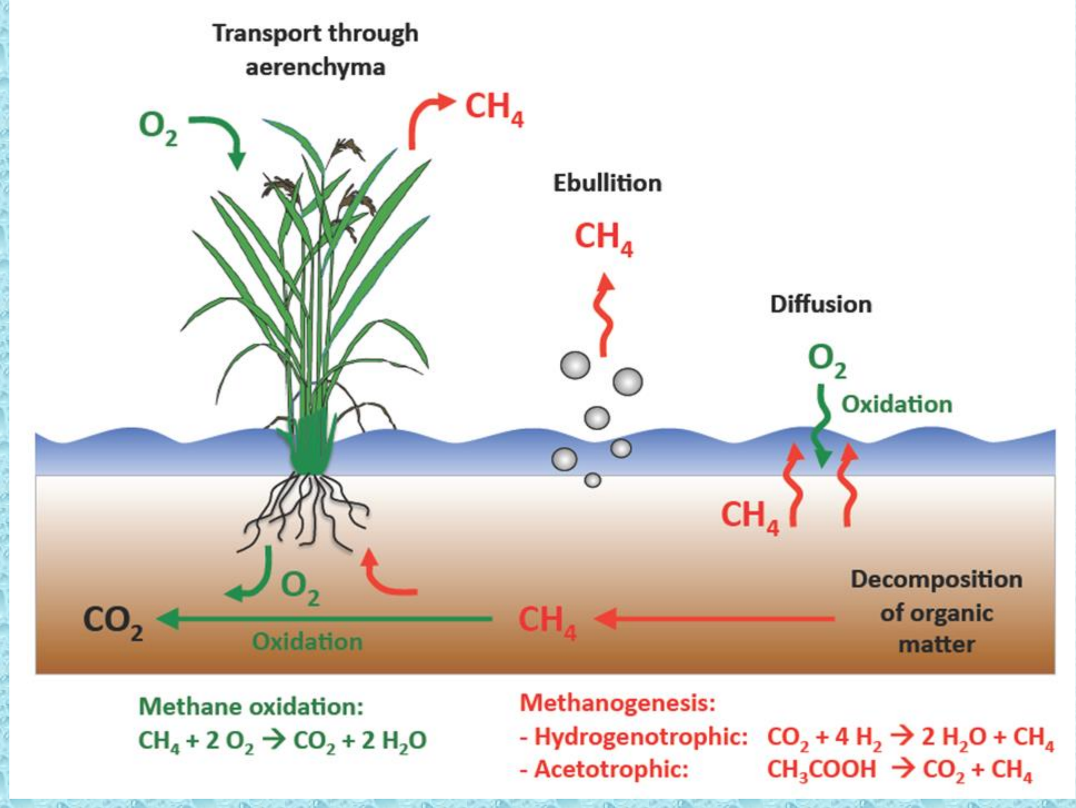

Figure 2. Generation and emission of methane from wet soils. (Courtesy of Josef Zeyer, ETH Zurich, Switzerland.)

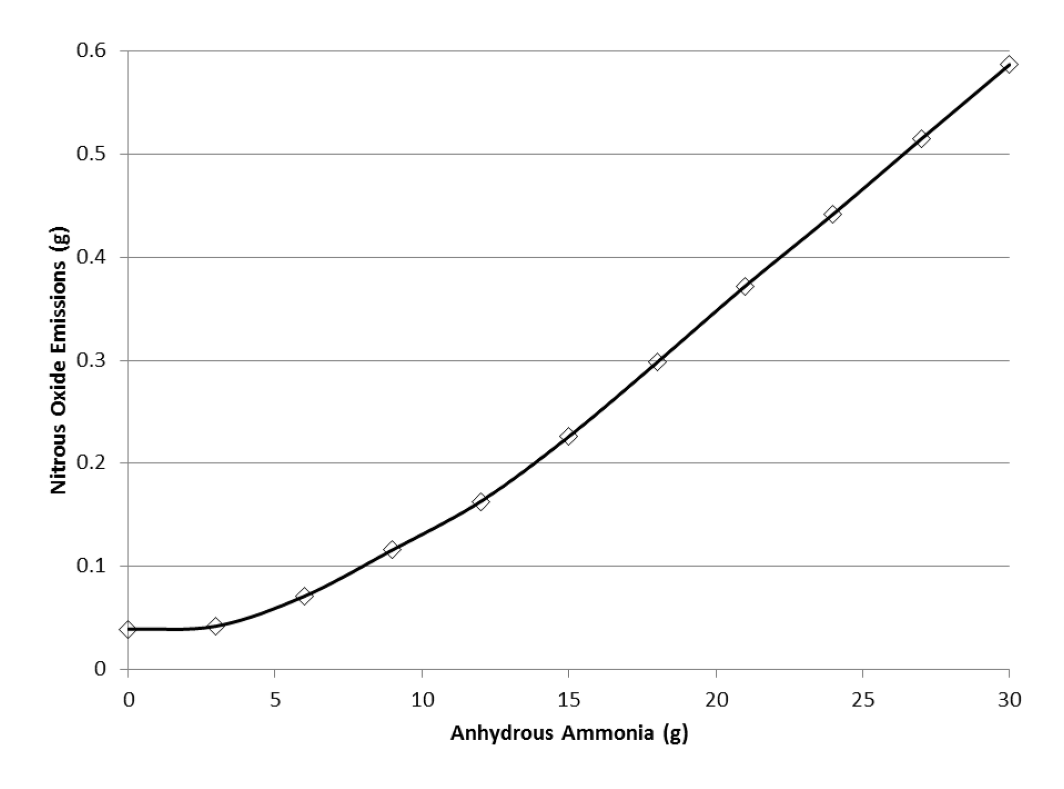

Figure 3. Modeled N_2O emissions per square meter at various application rates of anhydrous ammonia fertilizer. Data from Grant et al. (2006).

Soils and N_2O

- Agriculture accounts for about 58% of anthropogenic N_2O emissions
- Enhanced microbial production in expanding agricultural lands that are amended with fertilizers and manure is believed to be the primary driver behind increased atmospheric N_2O levels
- As nitrogen fertilizer applications increase, denitrification and the generation of N_2O in the soil also increases (Figure 3)

Soil Organic Carbon

- Early expectations were that increased atmospheric CO_2 would lead to increased plant productivity coupled with increased C sequestration by soil, this is known as the CO_2 fertilization effect
- Recent studies indicate the CO_2 fertilization effect may not be as large as originally thought
  - Increasing levels of ozone may counteract the CO_2 fertilization effect
  - Nitrogen limitations may negatively affect plant growth
- Increased temperature is likely to have a negative effect on C allocation to the soil

Soil Water

- Elevated CO_2 levels increase the water use efficiency and decrease evapotransporation rates of many plants
- Doubling atmospheric CO_2 has been shown to reduce seasonal evapotranspiration by 8% in wheat (*Triticum aestivum* L.) and cotton (*Gossypium hirsutum* L.)and by 9% in soybean (*Glycine max* (L.) Merr.) grown under day/night temperatures of 28/18°C
- However, the reduction in transpiration by soybeans was eliminated if the plants were grown under temperatures of 40/30°C
- In a study on rice doubling CO_2 decreased evapotranspiration by 15% at 26°C but increased evapotranspiration at 29.5°C
- Evapotranspiration rates appear to be temperature dependent, meaning the water benefits of increased atmospheric CO_2 could be reduced or lost in areas where temperatures rise too high

Conclusions

- There are still many things we need to know more about
- How will climate change affect the N cycle and, in turn, how the N cycle will affect C sequestration in soils
- Better understanding of soil water-CO_2 level-temperature relationships is needed
- Knowledge of the response of plants to elevated atmospheric CO_2 given potential limitations in nutrients like N and P and how that affects soil organic matter dynamics is a critical need

References

Brevik, Eric C. 2012. Soils and Climate Change: Gas Fluxes and Soil Processes. Soil Horizons 53(4): doi:10.2136/sh12-04-0012.

Grant, R.F., E. Pattey, T.W. Goddard, L.M. Kryzanowski, and H. Puurveen. 2006. Modeling the effects of fertilizer application rate on nitrous oxide emissions. Soil Sci. Soc. Am. J. 70:235–248.

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